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Origins of Airpower

**Hap Arnold's
Command Years and
Aviation Technology,
1936-1945***

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IN JANUARY 1936, Brig Gen Henry H. Arnold was transferred back to Washington, D.C. Maj Gen Oscar F. Westover had taken over as chief of the Air Corps and had convinced Gen Ma lin Craig, chief of staff, that he needed Arnold as his assistant. Another candidate for that job was General Headquarters (GHQ) Air Force commander Brig Gen Frank M. Andrews. Andrews and Westover had clashed regarding independence of the air arm. Westover, who had opposed separation from the Army through out his career, and Arnold, perhaps having learned a lesson about bucking the system at too high a level, agreed that remaining part of the Army held definite advantages for the Air Corps, particularly in the area of logistical support. From that point, Andrews's career took a different path from Arnold's. By 1939, Andrews had moved over to the General Staff under Gen George C. Marshall, and Arnold held command of the Air Corps. Arnold used this position to ensure, among other things, continued scientific and technological advances in his command.¹

Even before assuming command, Arnold chaired a committee formed in 1936 to examine how best to create a "Balanced Air Program." There was nothing unusual in his final report; in fact, it followed very closely the recommendations made previously by the Drum Board (a committee headed by Maj Gen Hugh Drum that was appointed to review and revise the Air Corps's five-year procurement plan). The numbers reflected in each report for personnel and planes were similar. Surprising today but realistic at that time, the forecast for airplanes required was only 1,399 in 1936, increasing to a meager 2,708 in 1941.² Although Arnold's report was primarily an attempt to reckon with depression budgets, no mention was made of scientific research or technological development. Rather, the pro-

gram's primary concern was to save dollars in all areas except purchasing airplanes.

In September 1937, Arnold modified the conservative approach which his Balanced Air Program report had taken. While addressing the Western Aviation Planning Conference, Arnold summarized his philosophy for creating a top-notch aeronautical institution in America:

Remember that the seed comes first; if you are to reap a harvest of aeronautical development, you must plant the seed called **experimental research**. Install aeronautical branches in your universities; encourage your young men to take up aeronautical engineering. It is a new field but it is likely to prove a very productive one indeed. Spend all the funds you can possibly make available on experimentation and research. Next, do not visualize aviation merely as a collection of airplanes. It is broad and far reaching. It combines manufacture, schools, transportation, airdrome, building and management, air munitions and armaments, metallurgy, mills and mines, finance and banking, and finally, public security-national defense. (Emphasis in original)³

In this statement, Arnold had issued the broadest description of the evolving technological system of airpower, even if he didn't make a distinction between empirical (based on observation) versus theoretical (based on calculations) research. If the Air Corps had little money for research and development (R&D), then perhaps universities and industry could be persuaded to find some. After all, it had been the Guggenheim Fund for the Promotion of Aeronautics that had funded the fledgling departments in that discipline at several universities almost a decade earlier.⁴ No matter the source, experimental research was the key to future airpower. Arnold had very cleverly linked Air Corps development to civilian prosperity in the aviation industry, hoping that civilian institutions would pick up the fumbled research ball while the Air Corps was struggling just to acquire planes. His ideas reflected the "Milikan philosophy,"

¹This article is the second part of a study of Gen H. H. Arnold and aviation technology, which began in the Winter 1996 issue.



USAF MUSEUM

Capt Homer Boushey in the Ercoupe at March Field.

that of bringing the center of aeronautical science in America to the California Institute of Technology (Caltech), which had shaped that university since the 1920s. This philosophy, coupled with Arnold's realization that airpower was a complex system of logistics, procurement, ground support bases, and operations, guided his vision for future growth.⁵ Arnold's approach to airpower development was actually the first notion of what became the military-industrial-academic complex after World War II.⁶

As was all too frequent an occurrence in these early years of aviation, a tragic aircraft accident took the life of General Westover on 21 September 1938. Arnold was now the top man in the Air Corps. Arnold's experience in Army aviation had prepared him for the tasks which loomed ahead, and now he was in a position to tackle these problems.

When Arnold "shook the stick" and officially took command of the Air Corps on 29 September 1938, many military aviation projects were under consideration both at

Wright Field and at the National Advisory Committee for Aeronautics (NACA) facility at Langley: radar, aircraft windshield deicing, jet assisted take off (JATO) system (which was actually a rocket), and a host of aircraft and engine design modifications. Many of these projects were related to the brand new B-17, an aviation technology leap in itself.⁷ Arnold wasted no time in calling the "long hairs" to a meeting at the National Academy of Sciences (NAS) under the auspices of the Committee on Air Corps Research, to solve these problems.⁸ It was no surprise that Arnold immediately accelerated Air Corps R&D efforts. In his first message as Air Corps commander, Arnold devoted a separate paragraph to the subject that reflected his public views on airpower. "Until quite recently," he said, "we have had marked superiority in airplanes, engines, and accessories. That superiority is now definitely challenged by recent developments abroad. This means that our experimental development programs must be speeded up."⁹ But his views were already commonly known to most airmen.

NACA's William Durand (center) was present for the initial JATO tests. Later he would be sworn to secrecy during development of the first American jet aircraft.



Assisting the speeding-up process, the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT) and the Massachusetts Institute of Technology (MIT) sent representatives to this NAS meeting. Vannevar Bush and Jerome Hunsaker of MIT grabbed the windshield deicing problem for their institution while openly dismissing JATO as a fancy job. Hunsaker called JATO the “Buck Rogers” job. Bush explained to Robert Millikan and Theodore von Kármán that he never understood how “a serious engineer or scientist could play around with rockets.”¹⁰ Arnold knew that GALCIT had already demonstrated some success in that area. Bush’s condescending attitude did not go over well with General Arnold. From that meeting onward, Arnold thought of Bush as something less than forward-looking, despite his excellent, even pioneering, record in electrical engineering. The case of Vannevar Bush was a classic example of how a talented individual had been dropped from confidence because of personal perceptions.

On the other hand, Millikan and Kármán, representing GALCIT, eagerly accepted the JATO challenge, an attitude that Arnold no doubt appreciated. JATO represented potential funding for the struggling GALCIT Rocket Research Project, initiated in 1936. This project, also known as GALCIT Project

#1, was established by Dr. Kármán and Dr. Frank Malina, and exists today as the Jet Propulsion Laboratory (JPL).¹¹

It was after this NAS meeting that the Arnold/Kármán association officially began. Arnold saw Kármán as a useful tool, a tap for recognizing undeveloped technologies. Kármán saw the Army Air Corps as a worthy recipient of his services. More importantly, however, the funding Arnold made available seemed bottomless and helped Caltech maintain its status as the leading aeronautical university in the country. Kármán was dedicated to helping the Army but was also dedicated to Caltech, the GALCIT, and Robert Millikan. Nonetheless, this alliance, above all others which Arnold held with scientists and engineers, proved one of the most significant and engaging collaborations in the early history of American airpower.

This meeting was just the beginning of Major General Arnold’s push to make science and technology an integral part of the Air Corps. He even invited General Marshall to a luncheon with the visiting scientists. Marshall wondered, “What on earth are you doing with people like that?” Arnold replied that he was “using” their brainpower to develop devices “too difficult for the Air Force engineers to develop themselves.”¹² The realization that civilian help was the only way to ensure that the Army Air Corps had the best



JET PROPULSION LAB

Kármán calculates the number of engines for a JATO-only takeoff (above). Twelve canisters were needed, the propeller was removed, and the nose was covered in safety posters (below). "What about tomorrow if I meet with an accident today?"



technology available was typical of Arnold. He didn't care where the devices came from; he only cared whether his Air Corps was utilizing them. By including Marshall in this circle of scientists, Arnold began winning support for advanced technology from the highest ranking Army officers.

Not only did Arnold utilize the advice of scientists, he gathered information from civilian aviators as well. One in particular influenced Arnold's commitment to technology. In late 1938, Arnold had exchanged letters with Charles Lindbergh, then touring Europe, which expressed Lindbergh's concern over US lethargy in airplane development. "It seems to me," Lindbergh wrote, "that we

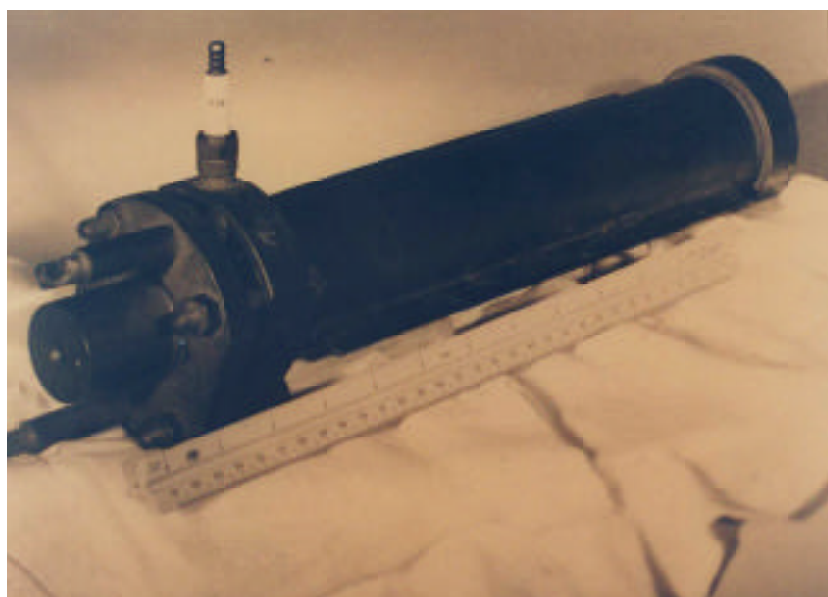


This view of the test run shows the test aircraft piloted by Clark Millikan.

should be developing prototypes with a top speed in the vicinity of 500 mph at altitude. . . . The trend over here seems to be toward very high speed.”¹³ This revelation worried Arnold. In March 1939, Arnold established a special air board to study the problems that Lindbergh had addressed. By April 1939, Arnold had convinced Lindbergh to accept an active duty commission as a member of the study group. This group, known as the Kilner Board, produced a five-year plan for research and development within the Air Corps. The report was shortsighted in many respects but did represent the immediate needs of the air arm. Jet propulsion and missiles, for example, were not even considered.¹⁴

Lindbergh’s impact was immediate but short-lived. In a written recommendation for the NACA, Lindbergh gained support for an expanded aeronautical research facility to be located at Moffett Field, California. The funding was approved on 15 September 1939. That same morning, Lindbergh spoke out against American participation in the Euro-

pean war on three major national radio networks. President Franklin D. Roosevelt tried to dissuade him from taking his views directly to the nation. After Lindbergh’s historic flight, the Guggenheim Fund had invested \$100,000 to subsidize a national tour expressly designed to generate support for aviation. By the late 1920s, Lindbergh had toured over 80 cities and influenced millions of Americans. “Lindy” was a skilled communicator. In many respects, he became the American spokesman for aviation.¹⁵ As such, his words carried an inordinate amount of influence. Fearing a major effect on public opinion, FDR promised Lindbergh a new cabinet post if he remained silent concerning American participation in the European war. Arnold had been caught in the middle of the presidential offer, but there was never any doubt in the general’s mind that Lindbergh would turn down such an offer and speak his own mind. Arnold was right. Consequently, Lindbergh “resigned” his commission, but Arnold



A JATO rocket engine, about 18 inches long.



In 1941, Air Chief Marshal Sir Charles Portal and Gen Arnold arranged the transfer of the Whittle technology. The photo was taken just prior to 6 June 1944.

had already taken his earlier warnings to heart.¹⁶

Arnold's public campaigns reflected Lindbergh's warnings. In January 1939, while speaking to the Society of Automotive Engineers in Detroit, Arnold—now the Air Corps's No. 1 man—reemphasized that America was falling behind in aircraft development. He attributed this failing to an inadequate program of scientific research. He stated:

All of us in the Army Air Corps realize that America owes its present prestige and standing in the air world in large measure to the money, time, and effort expended in aeronautical experimentation and research. We know that our future supremacy in the air depends on the brains and efforts of our engineers. . . .¹⁷

His dedication to continuous research, experimentation, and development was more focused, more defined than it had ever been, and now he carried the message across the country.

Arnold's official correspondence reflected the same commitment to R&D. In a memorandum to the assistant secretary of war dated

2 March 1939, Arnold vigorously defended proposed funding for research and development:

The work of the large number of aeronautical research agencies in this country should be afforded government support and encouragement only through a single coordinating agency which can determine that the individual and collective effort will be to the best interests of the Government. The NACA is the agency designated by law to carry out basic aeronautical research and its own plant and facilities cannot cover all phases of development. Furthermore, there are many public or semi-public institutions whose students or other research personnel are willing and anxious to perform useful investigation that will contribute to a real advancement of the various branches of aeronautical science.¹⁸

As a member of the NACA Main Committee since taking over the Air Corps, Arnold attended the committee meetings regularly and was familiar with the workings of the group. More importantly, he was acquainted with the other Main Committee members who together read like a “Who’s Who” in American aviation. Van Bush, Orville Wright, Charles Lindbergh, and Harry Guggenheim were all members of the Main Committee in 1939. Shortly after the 2 March memo was sent, Arnold established an official liaison between the NACA facilities at Langley Field and the Air Corps Materiel Division at Wright Field. Arnold assigned Maj Carl F. Greene to the post in an effort to tighten the relationship between the two organizations.¹⁹ The attempt to consolidate R&D programs was valiant, but time was running short. Conflict in Europe assured that the relationship would never mature.

The expanding war in Europe indicated that a posture of readiness was prudent and necessary for the United States. From the day that Germany invaded Poland in September 1939, Arnold realized that all American production efforts would be needed just to build enough aircraft of existing designs to create a fighting air force. “For us to have expended our effort on future weapons to win a war at hand,” he wrote Gen Carl A. Spaatz in 1946,



ROBERT ARNOLD

Arnold departs for England in April 1941 on the “Clipper.”

“would be as stupid as trying to win the next war with outmoded weapons and doctrines.”²⁰ While the outcome of the war was in question, and even though the United States was not yet directly involved, Arnold emphasized R&D only to improve weapons or aircraft by using technologies that were already on the drawing board. Essentially, from September 1939 until the spring of 1944, the majority of Army aviation R&D efforts were dedicated to short-term improvements in existing technologies.²¹

The total American production effort that followed Arnold’s early fears and resignation shocked everyone, including Arnold. By April 1943, the four-star general wrote to General Andrews, now air commander in the European theater, “By God, Andy, after all these years it was almost too much—I don’t imagine any of us, even in our most optimistic moments, dreamed that the Air Corps would ever build up the way it has. I know I . . . never did.”²² Airplane production became one of

the major reasons for American airpower's evolution into a massive technological system by 1944. Until the early years of World War II in Europe, the American aircraft industry was still in its infancy. The war forced it into early adolescence. Despite the many challenges inherent in the massive buildup of airplanes, Arnold still found time to push for a few untested technologies that showed exceptional promise while also pressing his field commanders to use "science" to advantage whenever possible.²³

The most spectacular of these technologies was the JATO program being pursued at Caltech since the NAS meeting in November 1938. Since it was most desirable to build aircraft that carried heavy bomb loads, the problems of high wing loading on initial takeoff became extremely important. "In many cases the maximum allowable gross weight of an airplane was limited solely by takeoff considerations. One of the many methods . . . proposed for the elimination of this difficulty involved the use of auxiliary rocket jets to augment the available thrust during takeoff and initial climb."²⁴ The net result was an increase in range for a desired payload. Frank Malina, "Homerjoe" Stewart, and the rest of the "suicide club" spent most of 1940 and the first half of 1941, developing the JATO system. By summer, Malina's team was ready to flight-test the device. Capt Homer Boushey flew an Air Corps Ercoupe from Wright to March Field, the selected spot for the test, late in July 1941. After a failed static firing resulted in a spectacular explosion, the rockets were affixed to the underside of the Ercoupe's wings, near the wing roots. Despite the failed test, it was decided to accomplish an anchored test-firing of the rockets attached to the plane. Although this test was more successful than the previous one, fragments of burning propellant and a small piece of a nozzle still burned a forearm-sized hole in the underside of the Ercoupe tail. "Well, at least it isn't a big hole," one of the onlookers observed. After the hole was patched, a successful airborne confidence firing test of the rockets was completed on 6 August, but the big test was yet to come.²⁵

On 12 August, filled with newfound confidence, Boushey strapped himself into the Ercoupe, now loaded with six JATOs, three under each wing. William Durand, long-time friend of Kármán, NACA charter member, and chairman of NACA's Special Committee on Jet Propulsion, had been invited to witness the JATO flight test. A test aircraft, a Piper Cub, piloted by Dr. Clark Milikan, idled next to the Ercoupe waiting for the soon-to-be-rocket plane to release brakes. Both aircraft revved their engines and released their brakes. In a matter of only a few seconds, having reached a predetermined speed, Boushey ignited his rockets. In a cloud of smoke, followed shortly by the crack of the rocket ignition, the Ercoupe catapulted into the air and over the 50-foot banner that marked the calculated height to be achieved after rocket ignition. The Piper Cub appeared to climb in slow motion. The JATO launch had been a remarkable success.²⁶

It was so successful that Kármán decided that it would be possible to launch the Ercoupe on rocket power alone, sans propeller. To cover up the fact that the prop had been removed, the Ercoupe nose was plastered with safety posters as if it were undergoing some form of repairs. "Be Alert, Don't Get Hurt!" At least the JATO team had a sense of humor. He calculated that 12 JATO engines would be required to accomplish the first American rocket-powered airplane flight. On 23 August, Boushey strapped in one more time. Kármán had calculated that at least 25 knots ground speed would be needed for the test to work properly, so it was decided to accelerate to that speed and then fire the rockets. But how to accelerate to the required speed without a working prop? A standard pickup truck fitted with a long rope pulled out on the runway in front of the propless Ercoupe. Boushey grabbed the rope like a rodeo bull rider and held on while the truck accelerated to the calculated 25 knots. Boushey released the rope, fired the rockets, now twice as loud and smoky, and hurtled 10 feet into the air on rocket power alone. He had enough runway left to make a safe landing straight ahead. Additional testing continued in both solid and

liquid auxiliary propulsion for the next decade.²⁷ Arnold pushed this program because it demonstrated potential for increasing the combat range of his heavy bombers.

Although not initially the most spectacular of all the Air Corps's scientific and technological research programs, Arnold's direct involvement in bringing the British Whittle jet engine to America began in April 1941 illustrated his personal commitment to technology and its application to the American war effort. As in 1913, Arnold did not care where the technology came from. If it benefited the Air Corps, he wanted it. So it was with the Whittle engine and the development of American jet aircraft.²⁸

Throughout 1938, Arnold had received Lindbergh's reports which suggested that some German pursuit planes were capable of speeds exceeding 400 MPH.²⁹ He had also assigned Lindbergh to the Kilner Board in an effort to project R&D requirements for the Air Corps. Whether Lindbergh had been "duped" by the Nazis on preplanned factory tours during his visits to Germany turned out to be irrelevant. Lindbergh had convinced Arnold that the Air Corps should begin research that would lead to a 500 MPH fighter. Arnold's constant quest for better technologies and equipment forced a confrontation with George W. Lewis, director of aeronautical research at NACA. Hap, at that moment not very happy, wanted to know "why . . . we [in the Army Air Corps] haven't got one [a 400-plus MPH fighter]." Lewis replied, "Because you haven't ordered one."³⁰ Arnold was furious. A lengthy dialogue followed during which Arnold discovered that Lewis was well aware that the technology to build faster planes had existed for some time. Lewis had not suggested building one because it was not NACA's function to dictate what the military should or should not build. To Arnold, NACA was not acting like a true team player. The general might have even considered Lewis's attitude unpatriotic.³¹ This incident overshadowed the many successful programs NACA had undertaken during Arnold's tenure.

Having lost trust in the workings and leadership of NACA, Arnold resorted to other civilian agencies in an effort to capitalize on Whittle's jet engine information made available to him by the combined approval of Lord Beaverbrook, who was in charge of all production; Sir Henry Tizard, scientific expert; Col Moore-Barbazon, minister of aircraft production; and Air Chief Marshal Sir Charles Portal in April 1941. Although NACA took steps toward jet engine development directed by the 1941 Durand Board (formed in March 1941 at Arnold's request), importing the plans and an engine from Britain was the general's personal achievement.³² In September, he took these plans and created a separate, supersecret production team that included Larry Bell of Bell Aircraft and Donald F. "Truly" Warner of General Electric (GE). GE was selected because of previous work done on "turbo-supercharging" (under the guidance of Sanford Moss), a process similar in nature to the turbojet concept.³³ The project military representative was Col Benjamin Chidlaw. This Bell/GE team was so secret that only 15 men at Wright Field knew of its existence. The contracts with GE had been handwritten and transmitted in person by Arnold's personal liaison, Maj Donald J. Keirn. Keirn recalled that the first GE contract was for a turboprop which was being built in Schenectady, New York, while the Whittle engine project was undertaken at West Lynn, Massachusetts. The three Durand Board engine teams—one at Westinghouse, a second sponsored by the NACA, and the first GE project—were unaware that Arnold had directed Chidlaw to get a jet in the air under absolute secrecy.³⁴ "Gen. Arnold," Chidlaw asked bewildered, "How do you keep the Empire State Building a secret?" Sternly, Arnold replied, "You keep it a secret."³⁵

The supersecret engine was assembled at Lynn, Massachusetts, under the project title "Super-charger Type #1." At Larry Bell's factory, the air frame project received an old program number so as not to arouse any suspicion. The workers themselves were segregated from each other so that even the members of the team were not totally sure



AFMCHQ: FROM THE OE COLLECTION

The "Supersecret" XP-59A team: Bob Stanley, Bell test pilot; Col Benjamin Chidlaw, program director; Maj Don Keirn and Maj Ralph Swofford, liaison officers; and Larry Bell.

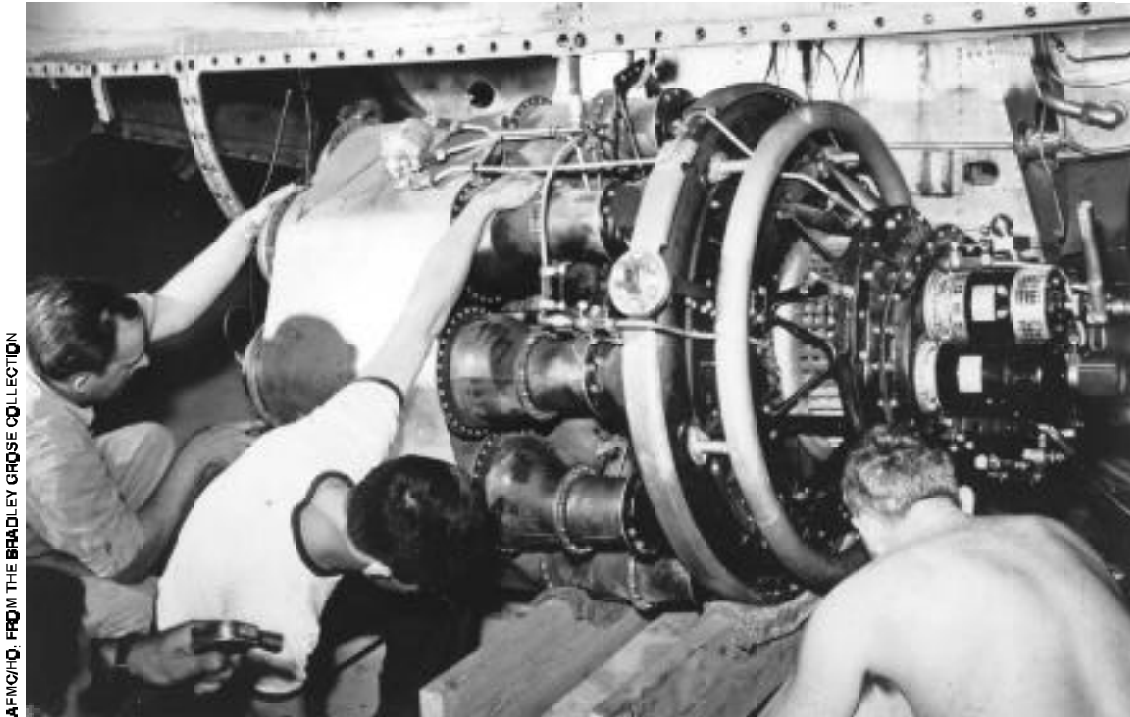
what they were building. The Army Air Forces (AAF) officer who was to be the first American military man to fly a jet, Col Laurence "Bill" Craigie, never revealed his mission, even to his wife, who found out about it in January 1944 with the rest of the country. Craigie recalled that "the only project I know of that was more secret was the atomic bomb."³⁶

On 2 October 1942, the Bell XP-59A flew three times. The first two flights were piloted by Bob Stanley, a Bell test pilot and Caltech graduate, and the third was flown by Colonel Craigie. In actuality, the plane had flown for the first time during taxi tests on 30 September and again on 1 October, but Larry Bell insisted that the first flight was not "official" until the brass hats were present as witnesses.³⁷ The internal "cloak of secrecy" was so effective that the general NACA member-

ship had heard only rumors of the technology. Only William Durand himself had been informed of Arnold's Whittle project but he was sworn to secrecy. The day the XP-59A flew, he was the only member of NACA who knew of the existence of the plane. In fact, he was at Muroc Dry Lake, California, the day of the first "official" flight.³⁸

It was not until 7 January 1944 that the rest of America, including Mrs. Craigie, found out about the flight. The *Washington Post* carried the inaccurate front-page headline "U.S. Making Rocket War Plane," which detailed the events of 15 months earlier.³⁹ The development of the XP-59A can legitimately be called the first Air Force "skunk works" project.

America's development of the jet engine was a typical example of how Arnold utilized technological advancement in attempting to improve Army Air Forces capability. Once



AFMCHQ. FROM THE BRADLEY GROSE COLLECTION

The XP-59A's I-A engine, "Son of Whittle."

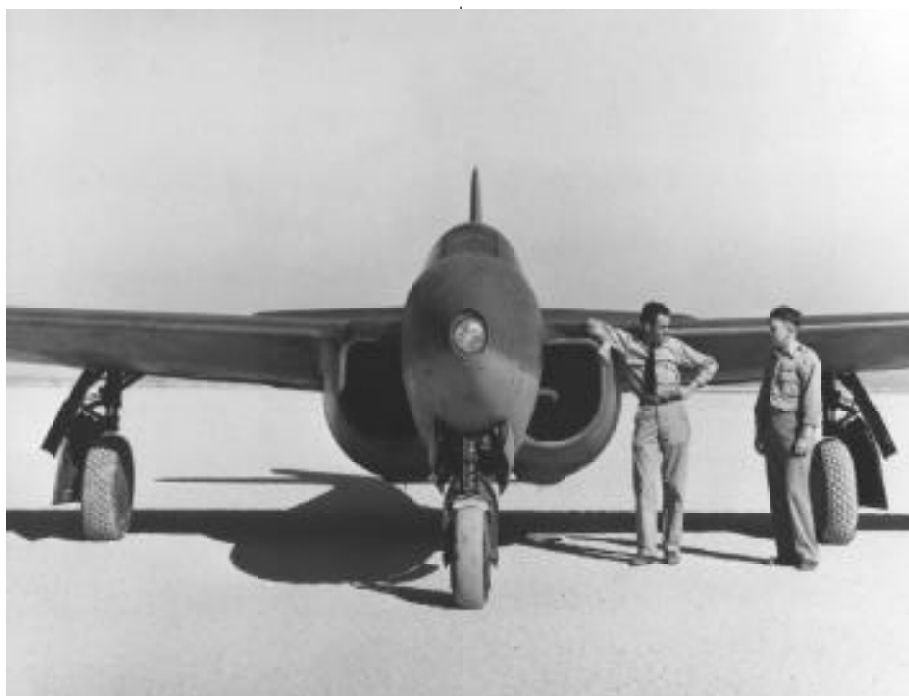
aware of a particular technology, he decided whether or not it was applicable to AAF airplanes or their combat capability. As late as January 1939, for example, Arnold had stated, "Because of the high efficiency and flexibility of operation of the controllable propeller as it exists today, it will be many years before any means of propulsion, such as rocket or jet propulsion, can be expected on a large scale."⁴⁰ But British engine developments, coupled with the underpinnings of early American turbojet concepts, and the promising work done at GALTIT Project #1 during 1940, convinced him that jets and rockets held significant potential for his air forces. Arnold always wanted the most advanced capabilities for his airplanes. But during the period 1939-1944, he wanted them within two years, no later.⁴¹

Once convinced of a program's efficacy, he gathered trusted scientists, engineers, and officers. Then, using the force of his personality, he directed what he wanted done with the



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Charles "Boss" Kettering (left), Arnold, and William S. Knudsen discuss production plans on 19 August 1940. The massive effort at times surprised even Arnold.



Bob Stanley and Col Laurence "Bill" Craigie flew the first three flights of the XP-59A "officially" on 2 October 1942 at Muroc Dry Lake, California.

technology. His teams were given considerable latitude in accomplishing the task and rarely failed to produce results.⁴² Some who had served on these "Hap-directed" task forces had private reservations about specified tasks. "You never thought the things he asked you to do were possible," one Douglas Aircraft engineer recalled, "but then you went out and did them."⁴³ Colonel Chidlaw's XP-59A team was one glittering example.

The XP-59A was an exceptional program in that it seemed to violate Arnold's general tendency to expend R&D efforts only on current production equipment from late 1939 until mid-1944. But Arnold saw the possibility for unbelievable capability from continuous research concerning jets. He envisioned aircraft capable of speeds exceeding 1,000 MPH and, despite criticism, completely believed in the future of jets. Arnold, having seen the British Gloster Meteor during its initial ground tests, realized that the first jets would not be the production models. Instead, he felt it more

important to get a jet aircraft flying and then work on the modifications necessary to make it combat worthy. Perhaps he remembered the lesson of Billy Mitchell's Barling bomber, which had provided vital data and production techniques even though it was an operational failure. Additionally, Arnold was able to get a substantial jump on the program by promising the British an improved formula for high-speed, high-temperature turbine blades in return for all available British jet experimental data and an engine. As it stood, jet aircraft did not have the necessary range to be of much value to the AAF, who would soon be flying missions from England to Germany. Consequently, until the problem of limited range was solved, the production effort was not pushed as hard as that of combat-proven aircraft. For that reason, American jets did not contribute directly to the World War II victory.⁴⁴ Arnold's push for the B-29 Superfortress can be better understood, however, in light of his perception of the importance of



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The GB-1 was specifically designed to keep aircraft away from enemy flak belts. Two were loaded on specially modified B-17s, and, although ineffective, were a stepping stone to "smart bombs."

combat range to mission success. This was particularly true for operations in the Pacific, although the airplane was not designed specifically for that theater.

Another Hap-directed project was established while the XP-59A was under development. In May 1942, Arnold ordered the formation of the Sea-Search Attack Development Unit (SADU). This unit was composed of scientists from MIT, the National Defense Research Committee (NDRC), and operations personnel from the Navy and the Army Air Forces. Total control of all assets having to do with submarine destruction—research and development, production, even combat execution—fell to this organization. Arnold viewed this specific task with such high priority that he attached the unit directly under his command, eliminating all bureaucratic obstacles to mission accomplishment.⁴⁵ Having seen "American-version" radars at Fort Monmouth, New Jersey, as early as May 1937, General Arnold was satisfied with the potential that radar had



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"Weary Willie" (sometimes "Weary Willy") aircraft served a dual purpose: they eliminated useless surplus from the inventory and furthered the development of remotely piloted missiles.

demonstrated and pushed hard for combat capability in that area.

The multicavity magnetron, which made shortwaveradar practical, was a British invention. In April 1942, Dr. Edward L. Bowles, from the MIT Radiation Laboratory (RADLAB), was assigned as a special consultant for radar installations. Arnold's commitment and Bowles's expertise helped make SADU an extremely effective unit. Arnold reminded Spaatz of the ultimate impact of SADU and the development of microwaveradar in a letter after the war. "The use of microwave search radars during the campaign against the submarine was mainly instrumental in ending the menace of the U-boats. Germany had no comparable radar, or any counter measures against it. In fact, for a long time the Germans were not even aware of what it was that was revealing the position of their subs so frequently."⁴⁶ As Arnold counted on Caltech for much of his aeronautical advice, he depended on MIT for similar advice concerning electronic advances, particularly radar.

In fact, it was German (and eventually Japanese) treachery in the conduct of the war, particularly with U-boats, that jolted Arnold into an attempt to rekindle an earlier pet project: the "Flying Bug." Although using the World War I surplus Bugs was actively considered during the war, the idea was finally dismissed due to the relatively short range of the weapon (only 200 miles). Other projects, however, did result from this initial rekindling. In the fall of 1939, Arnold wrote his old friend Charles Kettering, now vice president of General Motors, wanting to develop "glide bombs" to be used if war came. Arnold envisioned a device that could be used by the hundreds that might keep his pilots away from enemy flak barrages. He wanted the weapon to glide one mile for each one thousand feet of altitude, carry a sizable amount of high explosives, have a circular error of probability (CEP) less than one-half mile, and cost less than seven hundred dollars each. Kettering was convinced that it could be done fairly quickly. By December 1942, the GB-1 (glide bomb) was well under development and by

spring 1943 was being used in Europe. Although the GB-1 provided some protection to American airmen, it was highly inaccurate. Since the AAF held closely to the doctrine of precision bombing, the GB-1 was quickly shelved.⁴⁷ The GT-1, a glide torpedo, was somewhat more successful and saw some use in the Pacific theater. The development of the glide bomb series of weapons, which later included radio steering and television cameras, demonstrated one thing very clearly: General Arnold was not completely sold on manned, daylight, precision bombing doctrine.

As the air war progressed, B-17 and B-24 bombers literally began to wear out. These surplus bombers occupied valuable ramp space and even more valuable maintenance time. By late 1943, General Arnold had directed Brig Gen Grandison Gardner's Eglin Field engineers to outfit these "Weary Willies" with automatic pilots so that the airplanes, both B-17s and B-24s, could be filled with TNT or liquid petroleum and remotely flown to enemy targets. The idea behind Project Aphrodite was to crash the orphan aircraft into the target, a large city or industrial complex, detonating the explosives. General Spaatz utilized several of these "guided missiles" in the fall of 1944 against targets in Europe. They were largely unsuccessful because they were easy to shoot down before they reached the target area. At Yalta, shortly after the first Willies were used in combat, the British vetoed further Aphrodite missions because of possible German retaliation to the undeniable "terror" nature of the weapon. Weary Willies were grounded after Yalta, much to General Arnold's disappointment.

Interestingly, Project Aphrodite clearly involved the use of a nonprecision weapon system. Yet, Arnold staunchly supported its development well before Germany launched its first V-1 at England in the early morning hours of 13 June 1944. Not only were Willies capable of carrying large amounts of explosives, using them as guided missiles assured that none would remain in American stockpiles. Arnold remembered the painful Liberty engine lessons from World War I production

days. He didn't want B-17s flying a decade after this war was over as the DH-4 had done.⁴⁸

The importance of Aphrodite was not its impact on the outcome of the war. Arnold had no great hopes for the ultimate decisiveness of these "area bombing" weapons. Rather, Aphrodite demonstrated Arnold's willingness to supplement precision-bombing doctrine in an effort to save the lives of American airmen, particularly since he was feeling confident that the war in Europe was essentially under control by late spring 1944. In a staff memo, Arnold explained that he didn't care if the Willies were actually radio controlled or just pointed at the enemy and allowed to run out of gas.⁴⁹ Aphrodite did provide an opportunity to test new automated piloting technology in a combat situation. Additionally, and more importantly, destroying weary bombers made room for new airplanes that the prescient Arnold knew the air forces would need after the war ended.

Although Arnold was determined to rid the inventory of useless machines, in most combat situations he preferred manned bombers to Willies. In November 1944, Arnold reminded Spaatz of the salvage rules for damaged aircraft: "The accelerated activities of our fighting forces in all theaters makes it increasingly important that we utilize our material resources to the maximum, not only for the sake of the economy, but also in order that the greatest possible pressure be brought to bear against the enemy."⁵⁰ The experienced Arnold realized that to win a war one side must "try and kill as many men and destroy as much property as you can. If you can get me mechanical machines to do this, then you are saving lives at the outset."⁵¹ At this point, though willing to try nonprecision methods on occasion, Arnold realized that technology had not surpassed the abilities of manned bombers in accuracy or guile for accomplishing that mission.⁵²

Having established and tested his working pattern, General Arnold began actively planning for the future of airpower. NACA methodology under George Lewis left Arnold feeling let down, particularly in the field of

advanced aircraft research.⁵³ And although Wright Field had been vital to AAF production research and problem solving, personnel shortages made long-range studies a simple impossibility. Additionally, Arnold said he was irritated with the Materiel Division engineers' no-can-do attitude. Perhaps frustrated was a better description. Arnold once told a gathering of Materiel Division engineers, "I wish some of you would get in and help me row this boat. I can't do it alone."⁵⁴ Finally, any request for formal assistance from Vannevar Bush, now chief of the Office of Scientific Research and Development (OSRD), was not an option for Arnold—even though OSRD and its predecessor, the NDRC, had played a vital role during the war, particularly with radar and the development of the atomic bomb. Bush's attitude toward the JATO project had proved to Arnold that, although an excellent electrical engineer, Bush was no visionary. Bush once told Major Keirn, Whittle project liaison officer, that the AAF "would be further along with the jet engine had the NDRC been brought into the jet engine business," sarcastically adding, "but who am I to argue with Hap Arnold?"⁵⁵ The general and the OSRD chief held widely different views concerning military involvement in R&D that appeared diametrically opposed. Bush believed that the military should be excluded from any type of research other than production R&D. Arnold was adamant in the belief that long-term R&D also required military input lest the civilian world drive the development and implementation of airpower doctrine and policy. Their personal differences likely began to develop in 1938-1939 when Bush held the reins at NACA and Arnold served on its Executive Committee. It appeared that they just did not like each other.

For the most part, the problems discussed here have been related to the immediate needs of the AAF. The Whittle jet engine problem was, perhaps, the only exception. Arnold likely justified the project based on his acquisition of British plans and hardware, which essentially brought the Army Air Forces up to speed with the rest of the world. While dealing with these "short-term" research prob-



Left to right: Maj Gen Ben Chidlaw, Col Edward Deeds, Orville Wright, and Brig Gen Bill Craigie (the first military jet pilot) watch a P-80 being flown by a young Chuck Yeager at the AAF Fair at Wright Field in 1945. Orville had seen the Wrights' invention evolve into an immense technological system.

lems, which always involved available technologies, Arnold had formed strong opinions about the major participants in the American scientific and research communities. Lack of faith in NACA, exasperation with Wright Field, and the incompatibility of OSRD/NDRC philosophy with Arnold's convictions convinced him that, if he were to have an effective long-term plan for the AAF, an independent expert panel of free-thinking civilian scientists, given initial direction by the AAF, was the only answer. As he had said in different ways on several occasions, the future of American supremacy in the air depended on the brains and efforts of engineers and scientists. Now that the European war was winding down and the air war was definitely won, Arnold turned his thoughts to the distant future of the Army Air Forces. His call to action came in the form of a memo from an

old friend and supporter of airpower, Gen George C. Marshall. On 26 July 1944, Marshall wrote: "The AAF should now assume responsibility for research, development, and development procurement."⁵⁶ The impatient Arnold saw an immediate opportunity to act. Arnold had already decided that America's leading aeronautical scientist, Theodore von Kármán, whom he had known and trusted since the early 1930s, was the man he needed at the head of the Army Air Force Long Range Development Program.⁵⁷ In November 1944, the Kármán Committee became the AAF Scientific Advisory Group (SAG). In December 1945, SAG published *Toward New Horizons*, a report that served as Arnold's tool for linking technological advancement to the development of the US Air Force.

In summarizing Arnold's stance on technological advancement and R&D within the

Air Corps, three distinct time periods are revealed. Prior to the fall of 1939, Arnold supported long-term research that held promise for the entire aviation community over the coming decades. Immediately after the German invasion of Poland, Arnold shifted the posture of research and development in the Air Corps away from long-term projects toward short-term, quick-impact, operational-oriented R&D.⁵⁸ With few exceptions, Arnold's efforts in production and production R&D through 1944 provided massive fleets of technically advanced aircraft and weapons that were used by Americans and the Allies. The jet airplane—a bending of his “production R&D only” rule during the war years—held so much potential that Arnold felt obligated to take the risk involved in research and development in that area. Arnold himself saw jet aircraft as a “signpost to the future” rather than a tool for the present.⁵⁹

Arnold's personal contacts within the scientific/industrial sector, his World War I experience, as well as his tour at the Industrial College of the Army, were vital to the eventual success of American industrial mobilization efforts. He believed that it was more important to fight the war with the best weapons at hand, which included technological refinement for those existing systems, than to hang hopes on futuristic weapons that might not make it into the combat zone in time to make an impact on the outcome of the war. Arnold's pragmatism during the war (fall 1939 to late spring 1944) reflected the American tradition of empiricism, nicely explained by Tom Hughes in *American Genesis*. When Arnold felt that the inevitable victory was assured (late spring—early summer 1944), he once again turned his efforts to long-term planning for the Army Air Forces. His decisions—which shifted the basic direction of the Army Air Forces during the war years toward, then away, then back toward long-term R&D—established the scientific and technological foundation of today's modern Air Force.

□

Notes

1. H. H. Arnold to Mrs. S. H. Pool (Bee's mother), 22 February 1926, Robert Arnold Collection, Sonoma, California; and Herman S. Wolk, *Planning and Organizing the Postwar Air Force, 1943-1947* (Washington, D.C.: Office of Air Force History, 1984), 20-31.

2. “Report of Special Board Appointed to Make up a Balanced Air Program,” 5 August 1936. US Air Force Historical Research Agency (hereafter USAFHRA), 145.93-96; also see Wolk, 12-20.

3. Address of Brig Gen H. H. Arnold, assistant chief of the Air Corps, at the Western Aviation Planning Conference, 23 September 1937, USAFHRA, 168.3952-119. This belief in research may have been the result of earlier association with Dr. Robert Millikan. In 1934, Millikan had warned military officials through the executive Scientific Advisory Board, established in the summer of 1933, that “research is a peace-time thing and . . . moves too slowly to be done after you get into trouble.” Quoted in Michael S. Sherry, *Planning for the Next War: American Plans for Postwar Defense, 1941-45* (New Haven: Yale University Press, 1977), 123.

4. Richard P. Hallion, *Legacy of Flight: The Guggenheim Contribution to American Aviation* (Seattle: University of Washington Press, 1977). This book summarizes the entire story of the Guggenheim influence on the early years of American aviation.

5. In another speech, “Air Lessons from Current Wars,” before the Bond Club, Philadelphia, Pennsylvania, 25 March 1938, Arnold emphasized the foundations of airpower as not just planes but also “the number of flyers, mechanics, and skilled artisans available . . . and the size and character of the ground

establishments we lump under the general name air bases.” Ira C. Eaker Papers, Library of Congress (LOC), Washington, D.C., box 58, Arnold speeches (hereafter Eaker Papers).

6. Michael S. Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven: Yale University Press, 1987), 200-201. Also see Stuart L. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993).

7. Arnold to Oscar Westover, 18 May 1937. Murray Green Collection (hereafter MGC), LOC, box 55. JATO is pronounced jay'toe; for a list of NACA projects, see the NACA Executive Meeting minutes, National Archives Annex, College Park, Md.

8. Michael H. Gorn, *The Universal Man: Theodore von Kármán's Life in Aeronautics* (Washington, D.C.: Smithsonian Institution Press, 1992), 84; Ira C. Eaker, oral interview, 19 October 1978, USAF Academy Oral Interview series, USAFA. Eaker verified that Arnold and his staff reviewed intelligence reports on the air battles of the Spanish Civil War. One of Arnold's 1938 speeches covered the war in great detail and concentrated on the uses of airpower.

9. Maj Gen Henry H. Arnold, chief of the Air Corps, a message from the chief to the corps, 30 September 1938. National Air and Space Museum Archives, Arnold folder, Washington, D.C. (Hereafter NASM Archives). This message was Arnold's first as chief following Westover's death. Early influences on his quick action came from individuals like Lindbergh, Kármán, and even an informant who met with Arnold in Alaska during the 1934 B-10 flight.

10. Theodore von Kármán and Lee Edson, *The Wind and Beyond* (Boston: Little, Brown and Co., 1967), 243; also Kármán, oral interview by D. Shaughnessy, 27 January 1960, USAFA Special Collections, 2.

11. There are detailed accounts of this meeting in the Robert Millikan Collection, LOC, 9.15, roll 10. In a letter from Mason to Arnold, 5 January 1939, Mason summed up the results of the NAS meeting of the "long hairs."

12. Henry H. Arnold, *Global Mission* (New York: Harper and Brothers, 1949), 65-166; see Sherry, *The Rise of American Air Power*, 186-88.

13. Charles Lindbergh to Arnold, letter, subject: US Airplane Development, 29 November 1938, USAFHRA, 168.65-40.

14. Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II*, vol. 6, *Men and Planes* (1949; new imprint, Washington, D.C.: Office of Air Force History, 1983), 178-80.

15. Leonard S. Reich, "From the Spirit of St. Louis to the SST: Charles Lindbergh, Technology, and Environment," *Technology and Culture* 36 (April 1995): 365-67; also see Robert E. Herstein, *Roosevelt and Hitler: Prelude to War* (New York: Paragon House, 1989), 226-31; and Jeffery S. Underwood, *The Wings of Democracy: The Influence of Air Power on the Roosevelt Administration, 1933-1941* (College Station: Texas A&M Press, 1991), 111.

16. Charles A. Lindbergh, *Autobiography of Values* (New York: Harcourt Brace Jovanovich, Inc., 1976), 190-92.

17. "Performance and Development Trends in Military Aircraft and Accessories," speech given by Maj Gen H. H. Arnold before the Society of Automotive Engineers, Detroit, Michigan, 11 January 1939, 15-16, USAFHRA, 168.3952-119.

18. H.H. Arnold to the assistant secretary of war, memorandum, subject: Funding for Research and Development, 2 March 1939, USAFHRA, 167.8-33.

19. Arnold to Maj Carl F. Greene, letter (under NACA letterhead), subject: Assignment as Liaison Official, 1938, Kármán Collection; and NACA Executive Committee Meeting minutes, National Archives, College Park Annex, College Park, Maryland. Arnold served on the Executive (Main) Committee from October 1938 to April 1946.

20. Arnold to Gen Carl A. Spaatz, letter, subject: American Production Efforts in World War II, 9 November 1946, in Spaatz Papers, box 256. Arnold's detailed comments are in response to a news article critical of Air Force leadership during the war. Arnold feared that the hostile tone might influence funding in the Congress and warned Spaatz to read it carefully.

21. Maj Gen H. H. Arnold and Col Ira C. Eaker, *Winged Warfare* (New York: Harper & Brothers, 1941), 239. Arnold summed up what would become his wartime R&D philosophy: "Sacrifice some quality to get sufficient quantity to supply all fighting units. Never follow the mirage, looking for the perfect airplane, to a point where fighting squadrons are deficient in numbers of fighting planes."

22. Arnold to Lt Gen Frank Andrews, 29 March 1943, Andrews Papers, box 1, Library of Congress.

23. Arnold to Ira C. Eaker, 8 August 1943, Eaker Papers, box 50. "The more I think of our recent interchange of messages regarding German countermeasures against your bomber formations, the more I am convinced that you should have on your staff a free thinking technical man who is not tied down with current logistics, current modifications, and current procedure in any way. This man's main mission in life should be to sit there and weigh the information received . . . then advise you what action should be taken by you to outsmart the Germans. . . . This technician should also have a staff of two or three more scientists who would help him diagnose German moves and the motives behind them. At this writing, I have nobody in mind at all for this long-haired technical job, but if you think well of the plan I will rake up somebody and send him over to you, and I will also send the assistant scientists to sit there

and help him." This philosophy carried over into his directions to Kármán's mission in the fall of 1944.

24. C. B. Millikan and H. J. Stewart, "Aerodynamic Analysis of Take-Off and Initial Climb as Affected by Auxiliary Jet Propulsion," 14 January 1941, original report in the custody of Dr. Homer Joe Stewart, Altadena, California.

25. Dr. Homer Joe Stewart, interviewed by author, 21 July 1995, Altadena, California.

26. Dr. Durand had been named chairman of the Jet Propulsion Committee on 24 March 1941. This committee, instigated by Arnold and created by Vannevar Bush, the NACA Main Committee chairman, became known as the Durand Board. See Alex Roland's *Model Research: The National Advisory Committee for Aeronautics, 1915-1958* (Washington, D.C.: National Aeronautics and Space Agency, 1985), 189.

27. Stewart interview. Dr. Stewart confirmed the JATO story told in Kármán's autobiography, except he corrected the fact that Boushey was a captain, not a lieutenant; Kármán and Edson, 249-51; photos from the Jet Propulsion Lab Archives in Pasadena revealed the safety poster sayings.

28. The story of why America did not develop the jet engine earlier may be traced to its tendency toward utilitarian uses for "science." The story, a fascinating study in the evolution of American science, is expertly covered by Edward Constant's *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1981).

29. Charles Lindbergh to Arnold, letter, subject: JATO Test, 29 November 1938, USAFHRA, 168.65-40.

30. John F. Victory, oral interview, no. 210A, USAF Academy Oral Interviews, USAFA, Colorado. Victory was the first employee of NACA in 1915 and served as secretary throughout the period of this study.

31. *Ibid.* The story is too long to reproduce, but essentially Lewis sat at his desk in Washington and strictly adhered to the "advisory mission" of NACA. It was rare that NACA offered to expedite research or offer data without being asked by the Army Air Corps first. Arnold certainly saw this attitude as an obstacle to rapidly expanding the size and capability of the air arm; Hugh L. Dryden, *Columbia University Oral History Report* (CUOHR), 23. Dr. Dryden substantiates the basis of the 500 MPH story.

32. Vannevar Bush to Jerome Hunsaker, letter, subject: Jet Engine Development, 10 March 1941, Bush Papers, box 53, Hunsaker Folder, LOC; and *Global Mission*, 242.

33. Maj Gen Frank Carroll, interview with Murray Green, 1 September 1971, Boulder, Colorado, transcript in MGC, roll 12; also James O. Young, "Riding England's Coattails: The U.S. Army Air Forces and the Turbojet Revolution," manuscript (photocopy), Air Force Flight Test Center (AFFTC) History Office, Edwards Air Force Base, Calif., 1995.

34. Maj Gen Donald J. Keirn, interview with Murray Green, 25 September 1970, Delaplane, Va., transcript in MGC, roll 12. Keirn proves that there were two separate engine projects at GE at the same time; also see Roland, *Model Research*, for Durand Committee discussion.

35. Gen Benjamin Chidlaw, interview with Murray Green, 12 December 1969, Colorado Springs, Colo., transcript in MGC, roll 12. The question of why the United States was so late entering the jet age is expertly examined in Constant, 150-75 in particular. He cites the American tradition of empiricism as the reason that "radical" technologies were not produced ahead of more theoretically oriented countries like Germany and England.

36. Lt Gen Laurence Craigie, interview with Murray Green, 19 August 1970, Burbank, Calif., transcript in MGC, roll 12. Additional information on the Whittle engine can be found in the Arnold Collection, box 47. Walt Bonney, representing Bell Aircraft Corporation, was tasked to answer a flood of calls that resulted after the *Washington Post* story was released on 7 January 1944. In his press release, he emphasized the total secrecy of the project beginning in September 1941. Bonney did write a brief history of jet propulsion to placate the mass inquiries, but the secret nature of jet propulsion was protected. Walt Bonney, Bell

Aircraft Corporation, 11 January 1944, NASM Archives, Jet Propulsion folder. Arnold's, "Second Report of the Commanding General of the Army Air Forces to the Secretary of War," 27 February 1945, USAFHRA, 168.03, tells the story from his perspective. "Never has a plane been built in this country under greater secrecy," 76; also Young, "Riding England's Coattails," and Ezra Kotcher, "Our Jet Propelled Fighter," *Air Force* (March 1944), 6-8, 64.

37. Gen Laurence Craigie, USAF, Retired, and Gen Franklin Carroll, USAF, Retired, interviewed by Murray Green, in MGC, roll 12, US Air Force Academy Special Collections. Craven and Cate mistakenly state that Craigie was first to fly the jet; also see Daniel Ford, "Gentlemen, I Give You the Whittle Engine," *Air & Space*, October/November 1992, 88-98.

38. Frank Walter Anderson, *Orders of Magnitude: A History of NACA and NASA, 1915-1976* (Washington, D.C.: National Aeronautics and Space Administration, 1976), 31-48; Roland, 191-92; also Hugh L. Dryden, CUOHR. The original XP-59A has recently been placed in the National Air and Space Museum entryway where it will permanently reside in the company of the Wright Flyer, Apollo 11's command module, and the Bell X-1, to name a few.

39. *Washington Post* 7 January 1944, 1.

40. Maj Gen H. H. Arnold, "Performance and Development Trends in Military Aircraft and Accessories," address to the Society of Automotive Engineers, Detroit, Michigan, 14, USAFHRA, 3952.119.

41. Young, 12.

42. Laurence S. Kuter, "How Hap Arnold Built the AAF," *Air Force Magazine* (September 1973), 185-89.

43. F. W. Conant, CUOHR, in MGC, roll 12. Conant worked for Donald Douglas during this period—not to be confused with James B. Conant of MIT.

44. Brig Gen Godfrey McHugh, interview with Murray Green, 21 April 1970, Washington, D.C., transcript in MGC, roll 12; Colonel Lyon to Arnold, letter, September 1941, in MGC (Arnold Papers, box 43); Maj Gen Frank Carroll, interview with Murray Green, 1 September 1971, Boulder, Colo., transcript in MGC, roll 12; Arnold interview with T. A. Boyd (range was a major factor in determining which weapons or aircraft to build. The problems for Germany, at least in home defense, did not involve worries about range); and Ford, 88-98.

45. Craven and Cate, vol. 1, *Plans and Early Operations*, January 1939 to August 1942, 550.

46. Arnold to Spaatz, letter, 9 November 1946; excerpt from Stimson Diaries, 1 April 1942, in MGC, roll 12, documents Bowles's assignment as special consultant; Spaatz to Arnold, letter, 1 September 1944; Arnold to Spaatz, letter, 12 September 1944, in MGC, roll 12; Arnold to Oscar F. Westover, letter, 18 May 1937, in MGC.

47. Arnold to Charles Kettering, letter, subject: [GB-1], 3 November 1939, reprinted in MGC 6.38. This letter marked the beginning of controllable missile development, which included powered and nonpowered bombs and missiles of all kinds; Arnold to Spaatz, letter, n.d., in MGC (Spaatz Papers, LOC, box 8, record MM). "Obviously, this is an area weapon," Arnold wrote; Brig Gen Oscar Anderson to George Stratemeyer, memo, 2 April 1943, in MGC (Arnold Papers, box 137); and Craven and Cate, vol. 6, *Men and Planes*, 253-62.

48. Lt Gen Henry Viccellio, interview with Murray Green, 13 May 1970, San Antonio, Tex.; Arnold to George C. Kenney, letter, subject: Surplus B-17s, 25 October 1944; Arnold's War Diary, October 1944-December 1945, LOC. For a summary of Crossbow and Allied countermeasures, see Craven and Cate, vol. 3, *Europe: Argument to V-E Day*, January 1944 to May 1945, 525-46. Jacob Neufeld, in *Ballistic Missiles in the United States Air Force, 1945-1960*, points out that Lt Joseph P. Kennedy Jr., US Navy, was killed while flying a Weary Willie mission (page 10).

49. Lt Gen Fred Dean, interview with Murray Green, 20 February 1973, Hilton Head, S.C., transcript in MGC, roll 12; Arnold to Spaatz, letter, 22 November 1944, reprinted in MGC, roll 12.

50. Arnold staff memo, 2 November 1944, Arnold Papers, box 44; Arnold to Spaatz, letter, 22 November 1944, in MGC, roll 12. The different Willie projects should be clarified at this point. Weary Willie aircraft were flown to the enemy battle lines, then the pilot set the automatic pilot and bailed out in friendly territory. A Willie orphan was totally radio controlled and was remotely launched and guided into enemy territory sometimes from a mother ship that followed it to enemy territory. Aphrodite was also totally radio controlled, normally from the ground.

51. H. H. Arnold, E. L. Bowles, Louis Ridenour, phone transcript, 9 August 1944, in MGC, roll 12.

52. The circular error probable (CEP) for bombs dropped during World War II during American daylight missions was 3,200 feet for a 2,000-pound bomb. During Desert Storm, CEP for the same size bomb using precision guidance was three meters for over 80 percent of the bombs dropped. Dr. Richard P. Hallion, chief Air Force historian, interview with author, 28 August 1995. For an excellent discussion of the meaning of precision, see Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910-1945* (Washington, D.C.: Smithsonian Institution Press, 1995).

53. Roland, 192. Arnold did not give up on NACA altogether. In 1944 he pressured Donald Marr Nelson to push the construction of the Jet Engine Facility in Cleveland, Ohio. This facility became the test center for the engines that Arnold had kept secret from them in earlier years. Ironically, the facility was named after George Lewis, the research director most directly responsible for Arnold and Kármán's distrust.

54. Grandison Gardner, CUOHR, 11-13, 33. Gardner refers to Arnold's hesitation to use Wright Field engineers for important projects. Tactical research was even taken away from Wright Field and moved to Eglin AFB, Fla., under command of Gardner for this very reason; also see Lt Gen Donald L. Putt, interview by J. C. Hasdorff, 1-3 April 1974, Atherton, Calif., USAFHRA, Oral History K239.0512-724, 24.

55. Maj Gen Donald J. Keim, interview with Murray Green, 25 September 1970, Delaplane, Va., transcript in MGC, roll 12.

56. Marshall to Arnold and Gen Brehon B. Somervell, 26 July 1944, in MGC, roll 12.

57. Dr. I. A. Getting, interview by author, 9 November 1994. Dr. Getting believed that Arnold had consulted Dr. Edward Bowles before deciding upon Kármán to head the SAG. Arnold respected Bowles's opinion and had been impressed by his work on the SADU. He trusted his views on the direction for science and technology for the Air Force.

58. Arnold and Eaker, *Winged Warfare*, 238-39.

59. H. H. Arnold, "Air Forces in the Atomic Age," in Dexter Masters and Katharine Way, eds., *One World or None* (New York: McGraw-Hill, Co., 1946), 30; and Young. The debate over whether or not Arnold's staff had kept him as well informed concerning jet development in the United States as they could have is a complicated one. His actions in 1940, such as funding the high-speed tunnel at Wright Field, seem to indicate that he was aware of the Kotcher Report of 1939. Remember, too, that these developments would have taken place during what I call Arnold's early "Technology Phase II, September 1939-Spring 1944," when production and production R&D projects took precedence over all other projects. The turbojet engine, in the early days, did not show the potential for completion within the two-year restriction that Arnold imposed on R&D projects. Once the Whittle information became available in April 1941, the American timetable moved dramatically forward, hence Arnold's apparent late push into jet propulsion. Actually, this fit well with his wartime R&D restrictions.